Fabrication of Non-Biofouling Nanochannel Sensor in Dimethacrylate-Based UV Curable Polymers by UV-Nanoimprint Lithography (NIL)

Junseo Choi and Sunggook Park
Mechanical and Industrial Engineering Department and Center for BioModular Multi-Scale Systems for Precision Medicine (CBM^2), Louisiana State University,
Baton Rouge, LA 70803
sunggook@lsu.edu

Nanofluidic devices have drawn significant interest in biomedical applications due to their potential for controlling, manipulating, and sensing single biomolecules. In our recent investigation, we fabricated a noble nanosensor in polymer substrate and successfully achieved single nucleotide identification through molecular-dependent Time-of-Flight (ToF) measurements using nanoscale electrophoresis [1]. Label-free determination of molecular-dependent ToF was made possible by employing two sub-10 nm in-plane nanopores positioned on either side of the nanochannel column. Notably, the accuracy in identifying four 2-deoxyribonucleoside 5'-monophosphates (dNMP) was found to be dependent on the nanochannel column length, reaching a remarkable 94% with a 5 μm column length. In the work, the sensor fabrication involved the use of a poly(ethylene glycol) diacrylate (PEGDA) as substrate via a cost-effective, high-throughput nanoimprint lithography (NIL) technique suitable for scalable production. PEGDA was selected due to its non-biofouling properties and hydrophilicity that eliminates the need for surface treatment for wetting. Additionally, PEGDA's low surface charge density minimizes electroosmotic flow (EOF) during electrically driven biomolecule detection [2]. Despite such merits, PEGDA exhibited insufficient chemical and structural stabilities due to the hydrogel nature, leading to a drift of the transient current background signal over a 3–5 hour operational period. Thus, there is a need to develop alternative materials for the substrate of nanofluidic devices which offer improved chemical and structural stabilities while still maintaining the non-fouling, good wetting, and low EOF characteristics of PEGDA.

In this work, we demonstrate the use of di(meth)acrylate-based UV resin such as glycerol 1,3-diglycerolate diacrylate (GDM), epoxy ester 70PA, or 1,3-glyceryl dimethacrylate (GDD), each featuring varying hydroxyl group numbers, for sensor development as a viable alternative to PEGDA [3]. UV-curable resins were synthesized by combining each di(meth)acrylate monomer with the photoinitiator (Irgacure 907). Sensor fabrication involved photolithography and focused ion beam milling on a Si substrate, followed by replication with the UV resins on a PMMA backbone substrate using UV-NIL. This process was completed by COC cover sheet bonding, resulting in an enclosed nanofluidic sensor. Our presentation will delve into the translocation behavior of dNMPs through these bonded sensors.

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